

Tau Neutrino Optimization for LBNE/DUNE

Michael Dolce

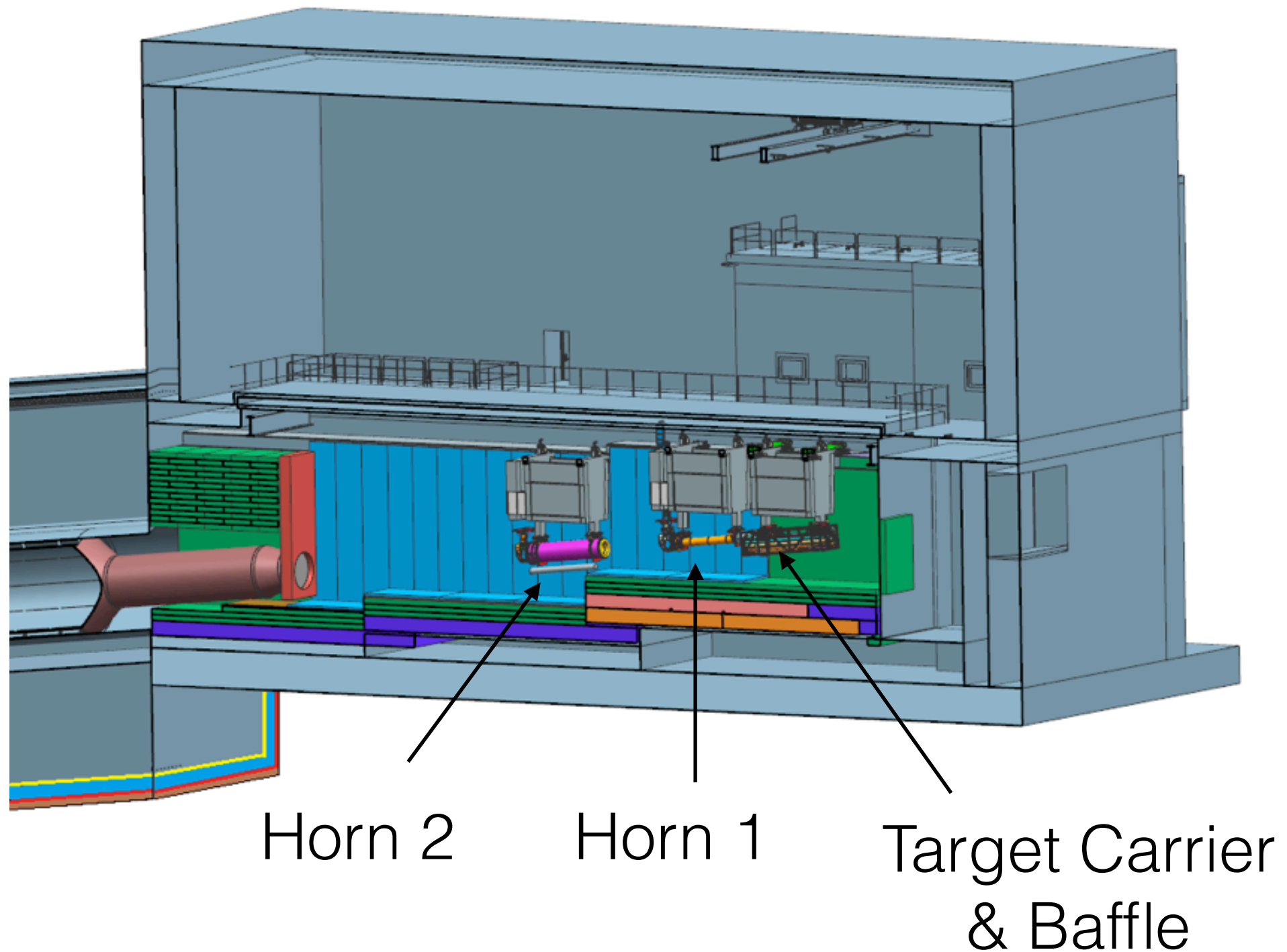
Optimize nu-tau appearance in referenceGeometry

- Coded a probability function that a muon neutrino will oscillate into a tau neutrino, which took in four parameters from the equation

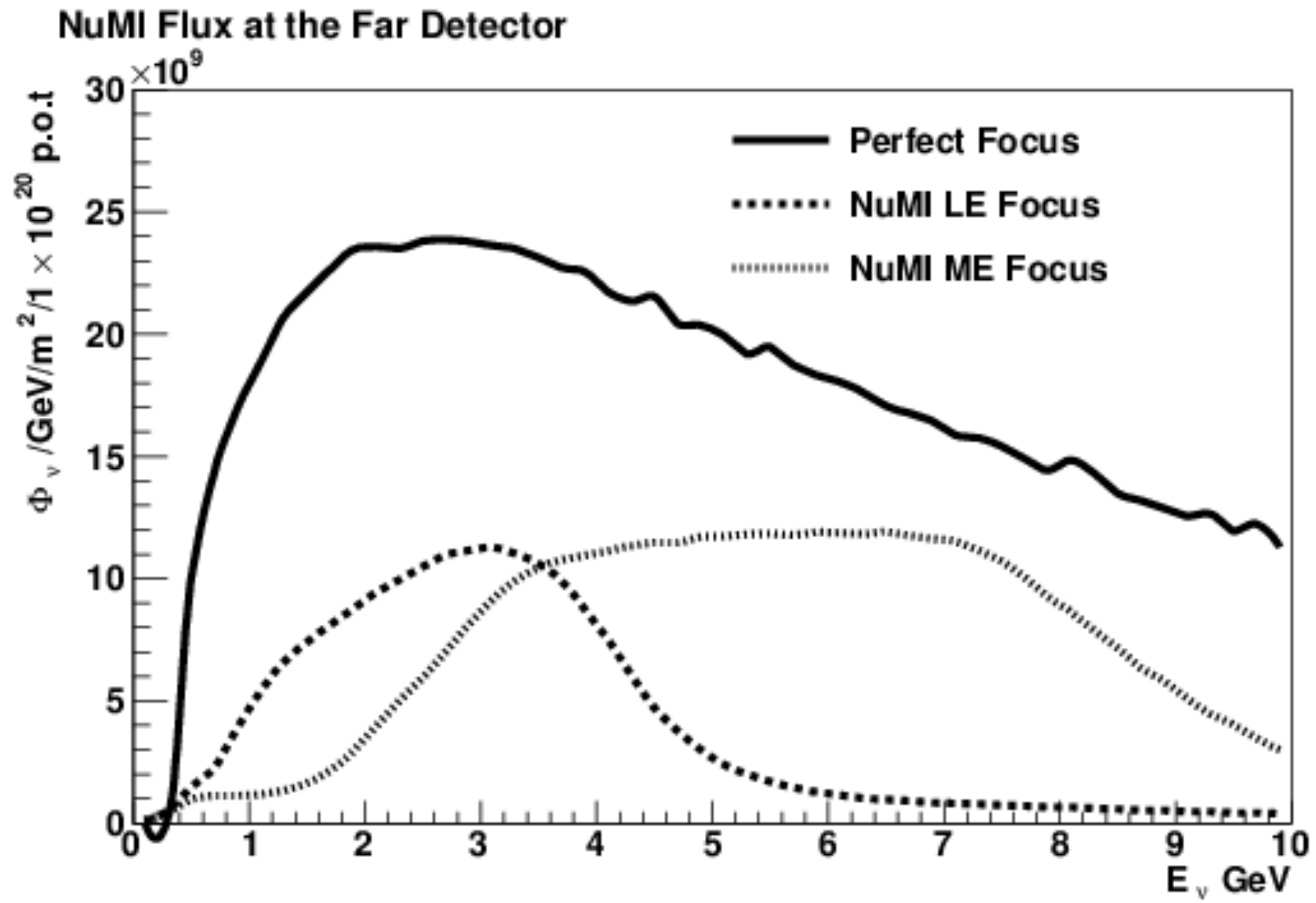
$$P_{\alpha \rightarrow \beta, \alpha \neq \beta} = \sin^2(2\theta) \sin^2 \left(1.27 \frac{\Delta m^2 L [\text{eV}^2] [\text{km}]}{E [\text{GeV}]} \right).$$

- Where $\alpha = \text{nu-mu}$, $\beta = \text{nu-tau}$, $\theta = \theta_{23}$, and $\Delta m^2 = \Delta m_{32}^2$.
- The PDG values for normal hierarchy were used ($\sin^2(2\theta_{23}) = 0.999$, $\Delta m_{32}^2 = (m_3)^2 - (m_2)^2 = 2.44\text{e-}03 \text{ eV}^2$).
- The first and second mass states are similar in mass compared to the third, so we used the approximation $\Delta m_{32}^2 = \Delta m_{31}^2 = 2.44\text{e-}03 \text{ eV}^2$.
- The neutrino cross sections were read from a GLoBES data file, and neutrino cross-section/energy was plotted and a function was fitted.
- Function fitted up until 120 GeV, or the power of the beam.

DUNE reference design with NuMI style horns

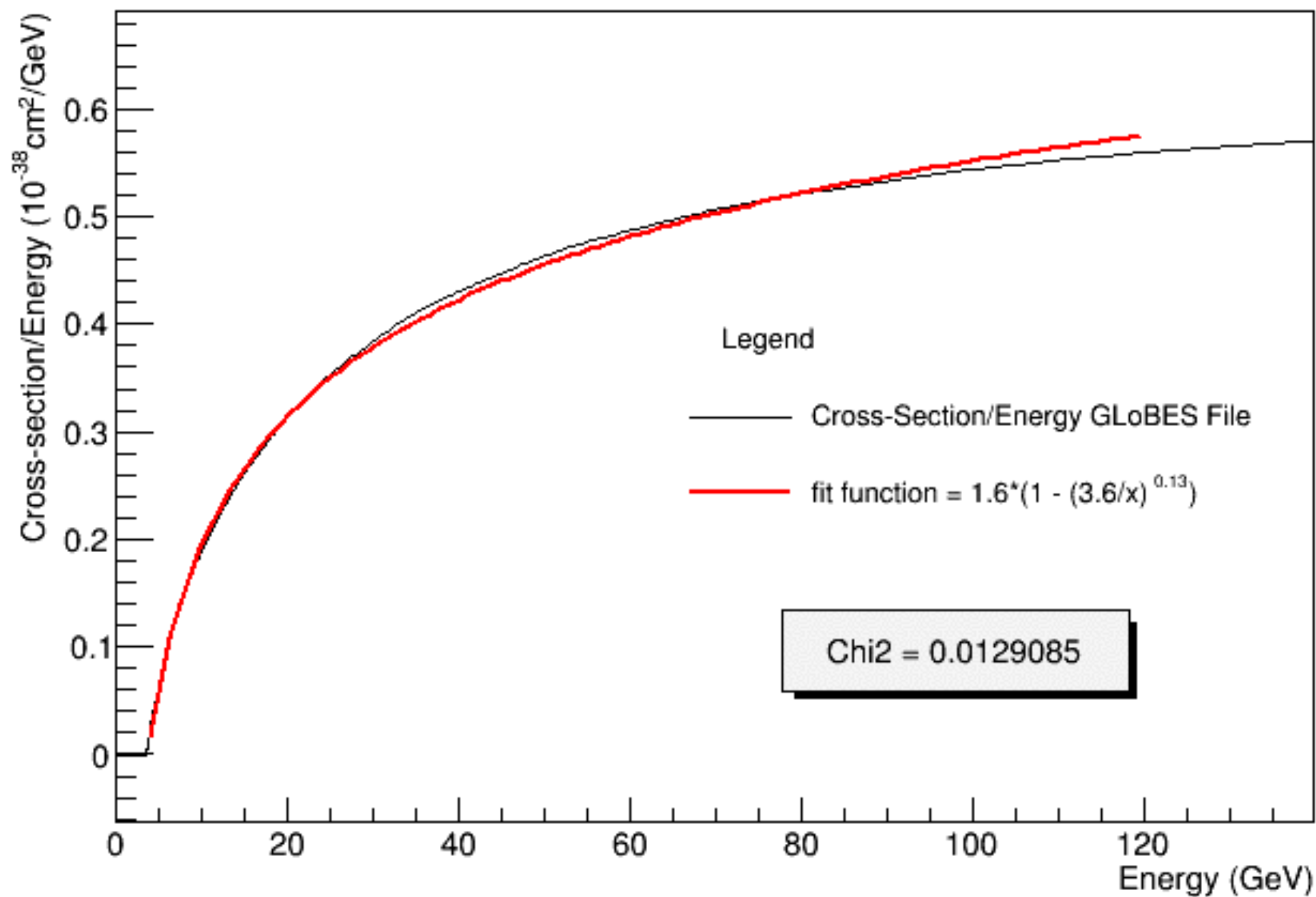


From ‘LBNE/DUNE CDR Volume 3: The Long-Baseline Neutrino Facility for DUNE’



P. Adamson et al., "The NuMI Neutrino Beam" Nucl.Instrum.Meth. A806 (2016) 279-306

Nu-Tau Cross Sections



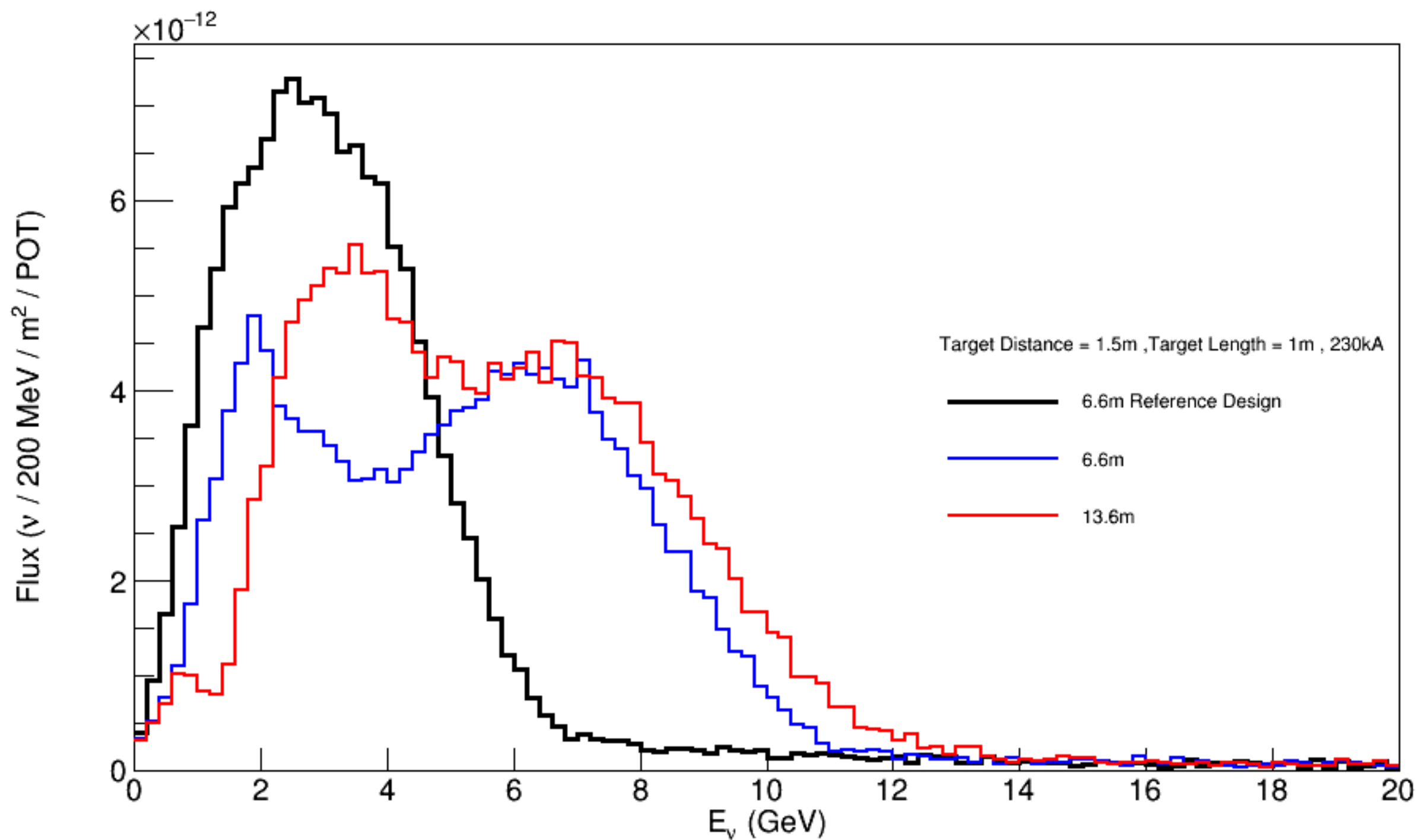
- The target distance was moved upstream to 1.5m from Horn 1 compared to original 42cm. New location is 0.5m from the beam.
- The parameters tested were the location of Horn 2, currents in Horns 1 and 2, and the length of the target.
- The flux, probability function, and neutrino cross section function (multiplied by neutrino energy) were multiplied together to produce the tau neutrino events and plotted against the neutrino energy (GeV).
- Total number of events computed assuming $1e21$ POT and a 40 kt detector.

referenceGeometry

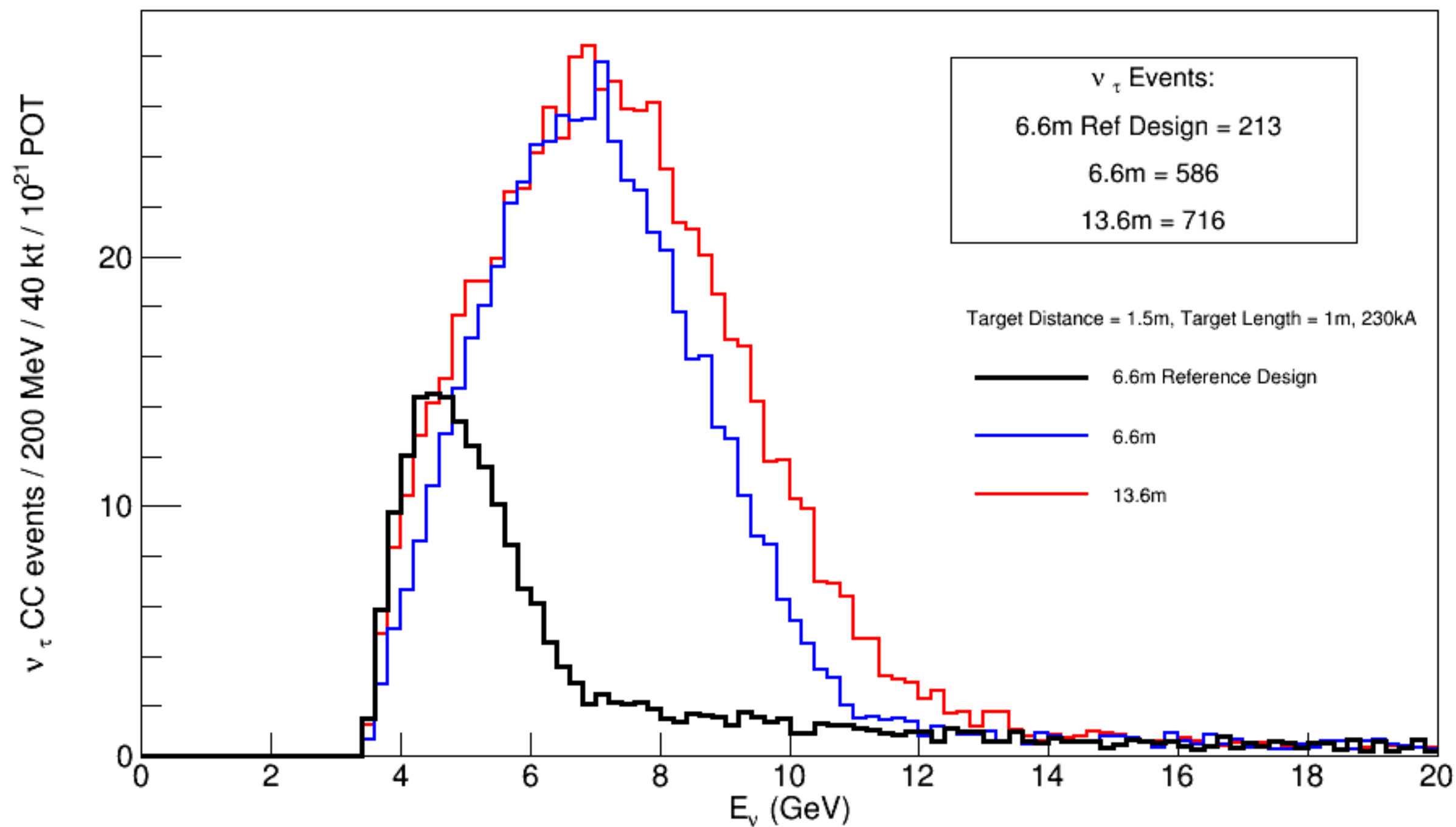
Target length	1 m
Target width	0.006 m
Target height	0.02 m
Target distance to end of beam	0.42 m
Beam power	120 GeV
Horn 1 & 2 current	230 kA

- Compared the target length of 1m to the target length of 2m in the referenceGeometry design at all distances (from 0m-7m) at 230kA.

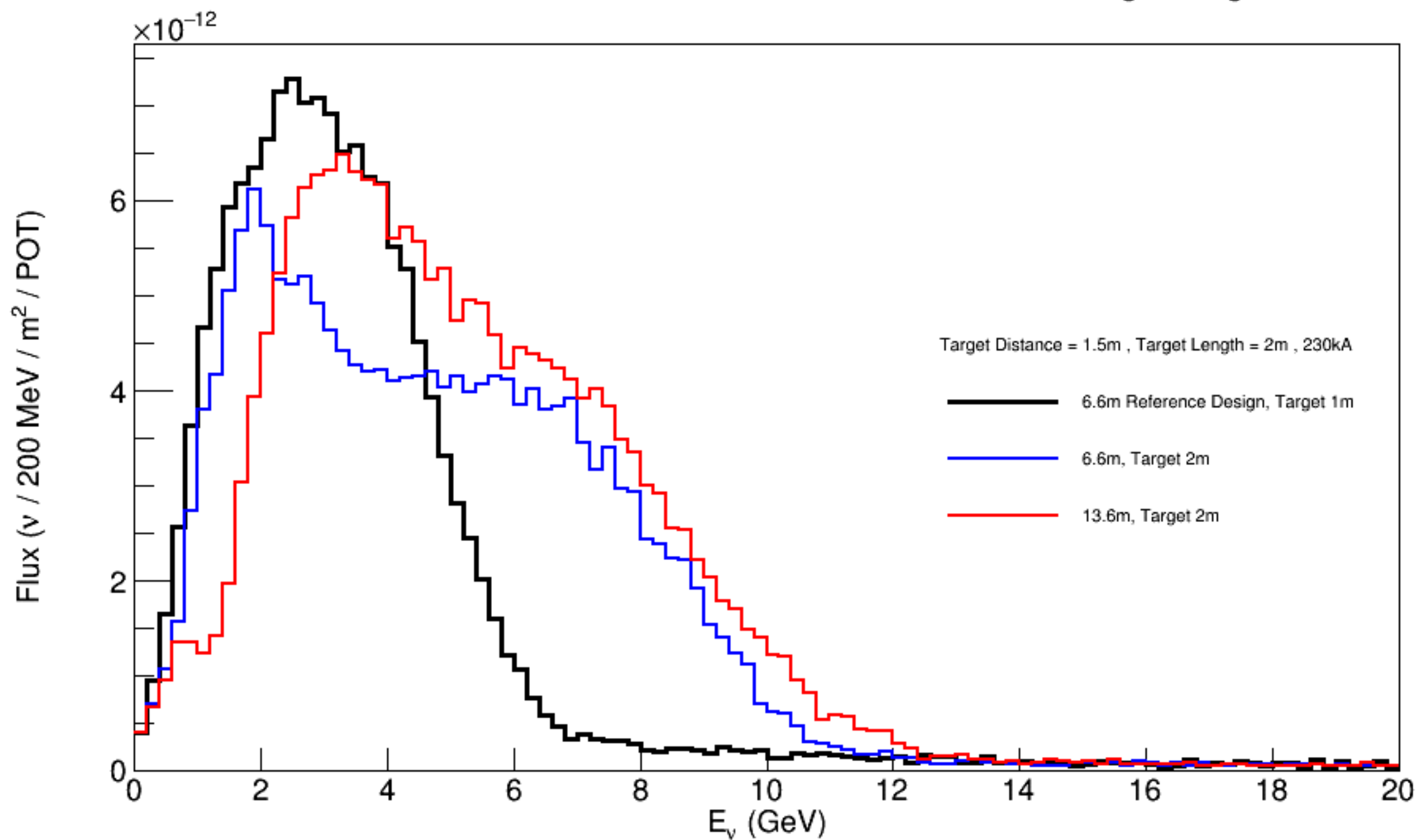
Muon Neutrino Flux with Horn 2 Moved Downstream w/ 1m Target Length



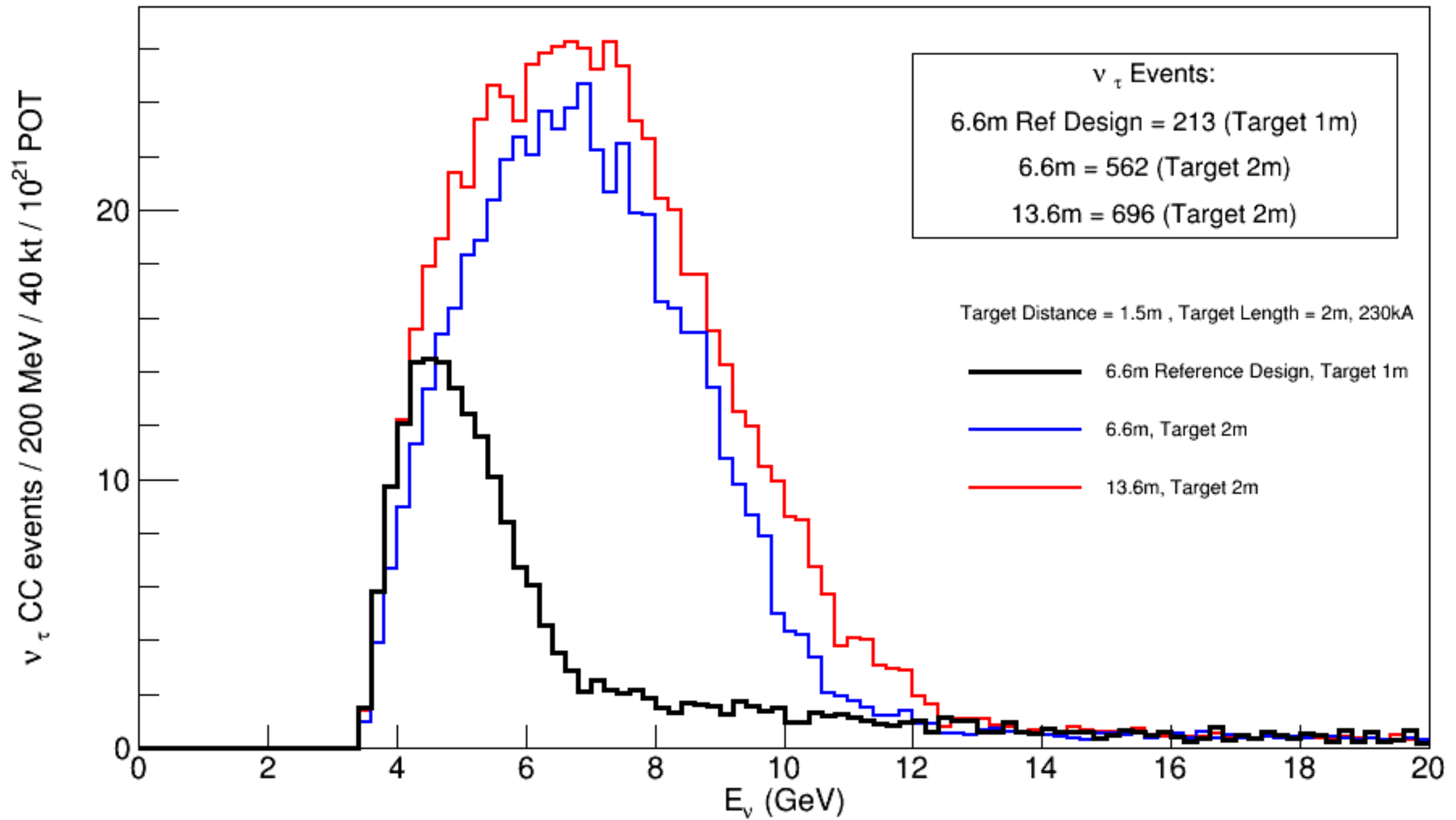
ν_τ CC events with Horn 2 Moved Downstream w/ 1m Target Length



Muon Neutrino Flux of Horn 2 Moved Downstream w/ 2m Target Length



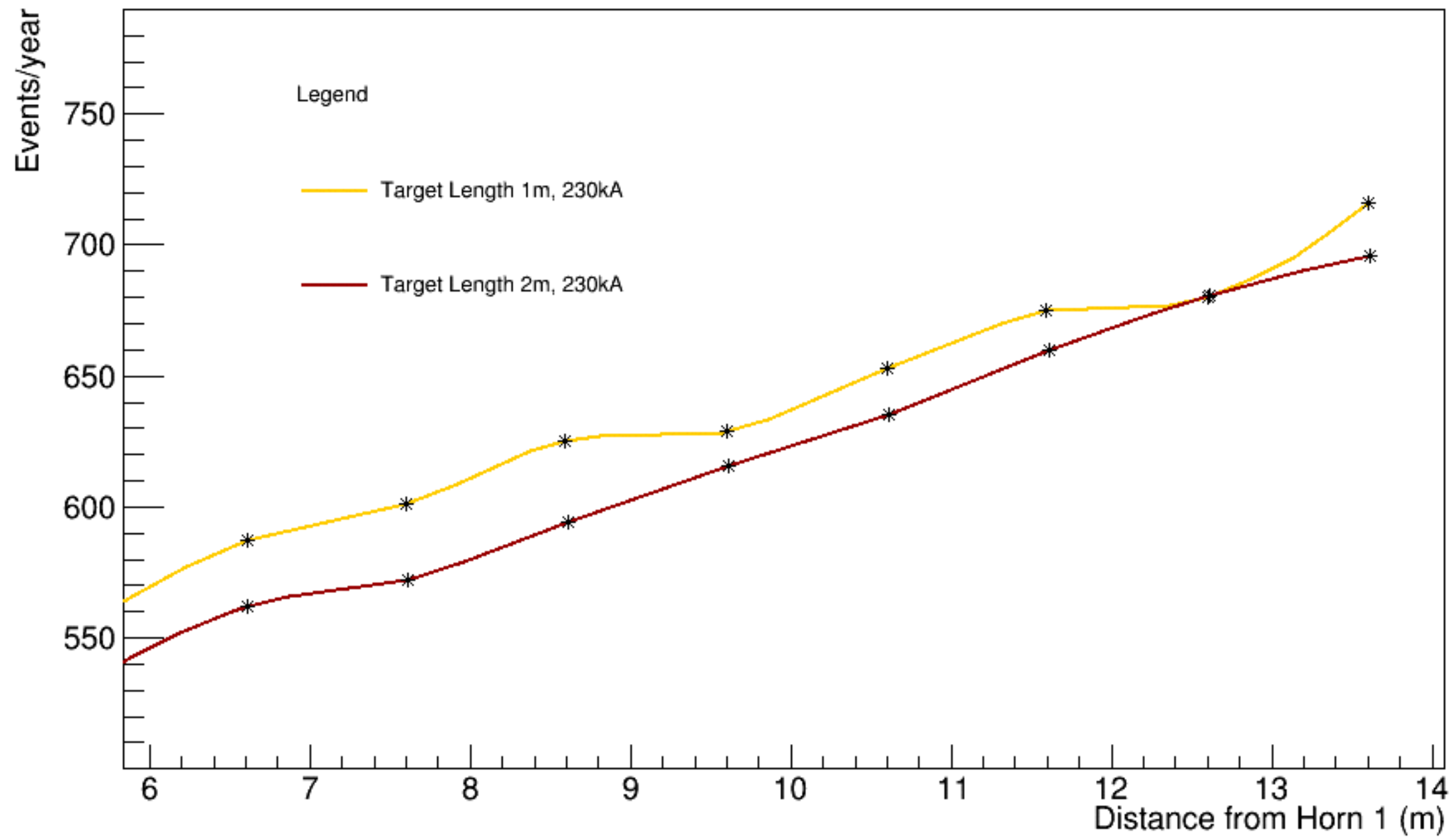
ν_τ CC events with Horn 2 Moved Downstream w/ 2m Target Length



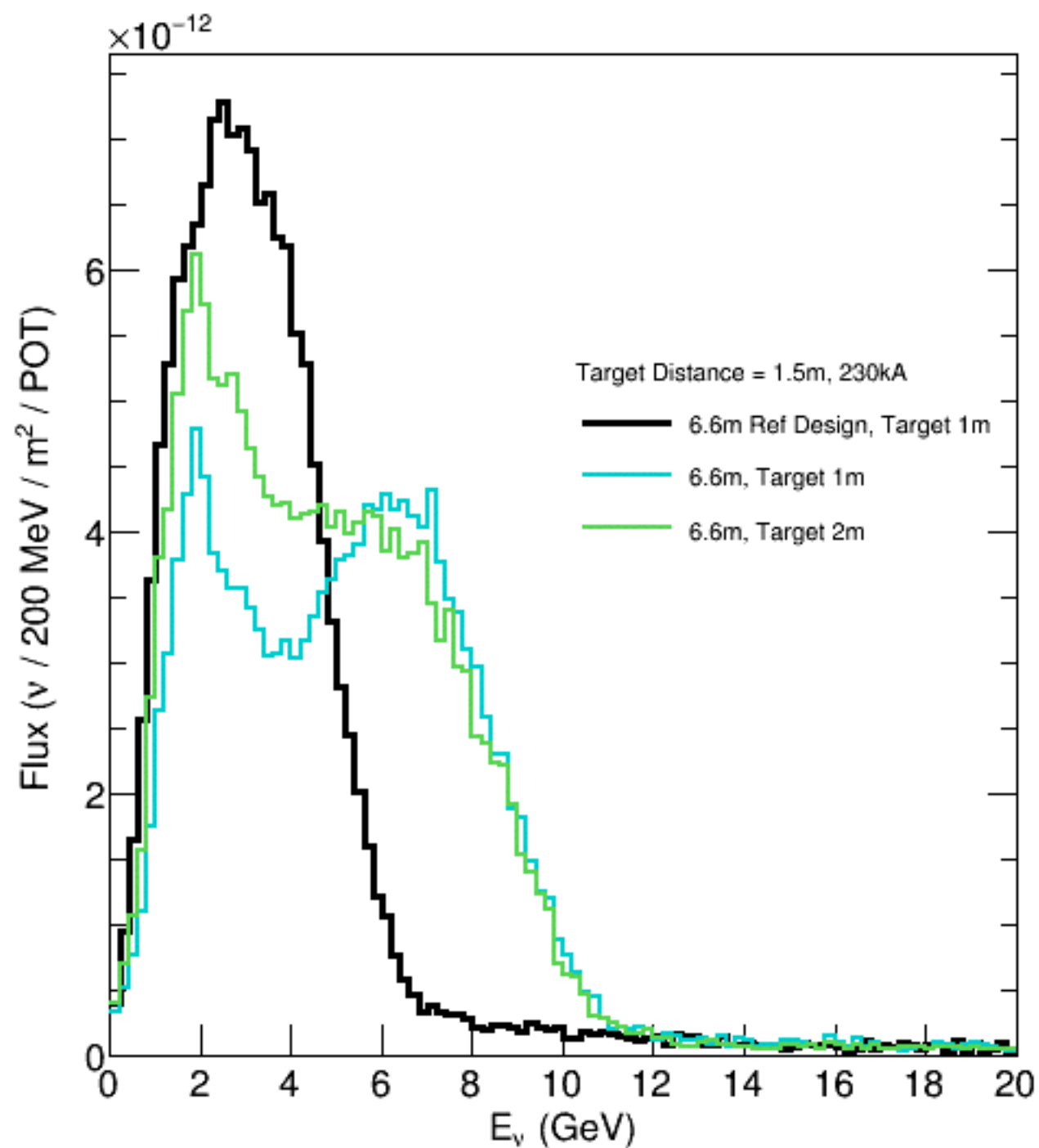
Target Length: 1m vs. 2m
Target Distance to Horn 1: 1.5m
Horn Current: 230kA

Horn 2 Distance from Horn 1 (m)	Rate (events/yr) for Target Length 1m	Rate (events/yr) for Target Length 2m
6.6110	586	562
7.6110	601	572
8.6110	624	594
9.6110	628	616
10.6110	652	635
11.6110	675	660
12.6110	680	681
13.6110	716	696

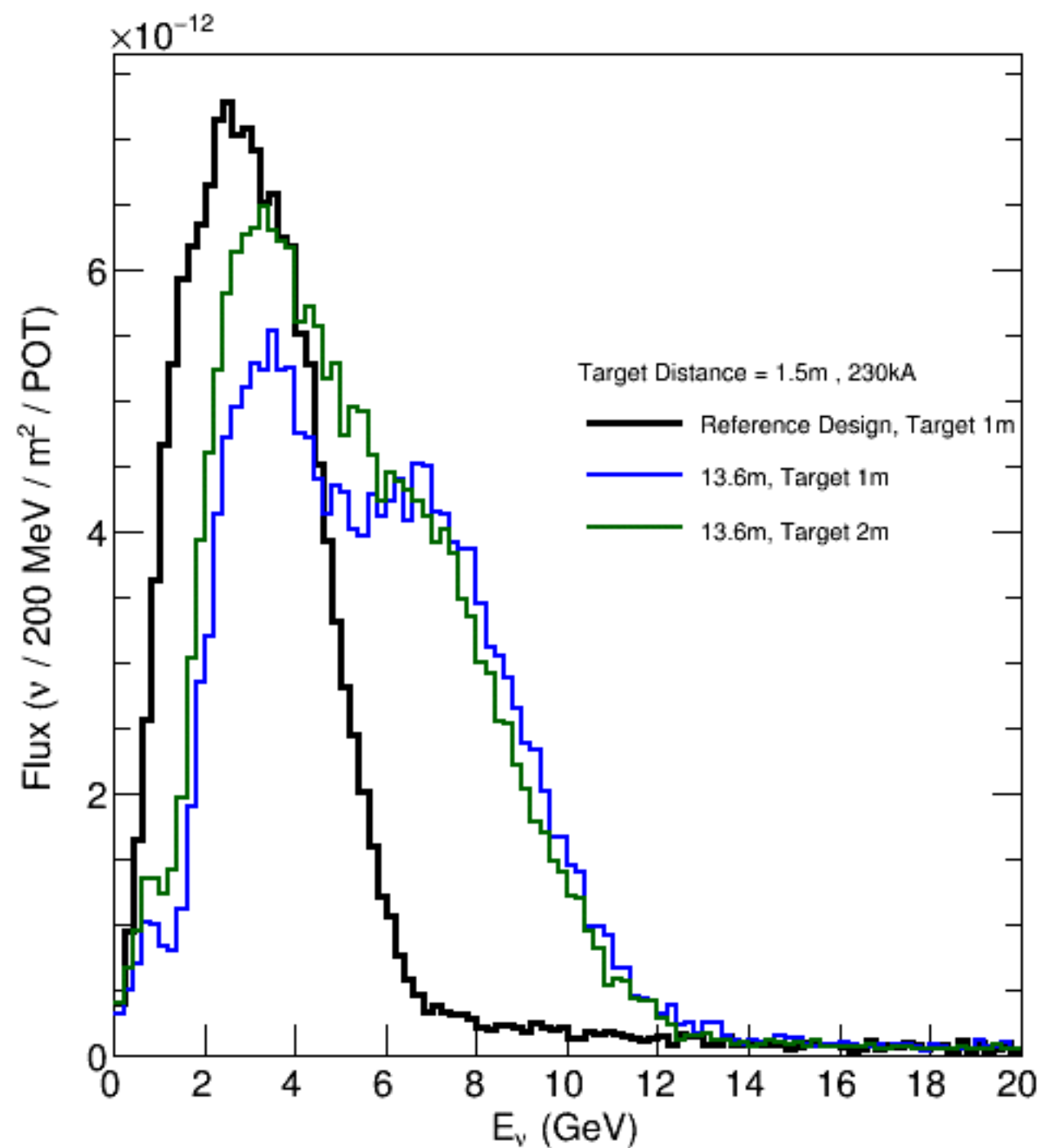
Events/Year vs. Horn 2 Location



ν_μ Flux with 1m & 2m Target Length and 230kA



ν_μ Flux with 1m & 2m Target Length and 230kA

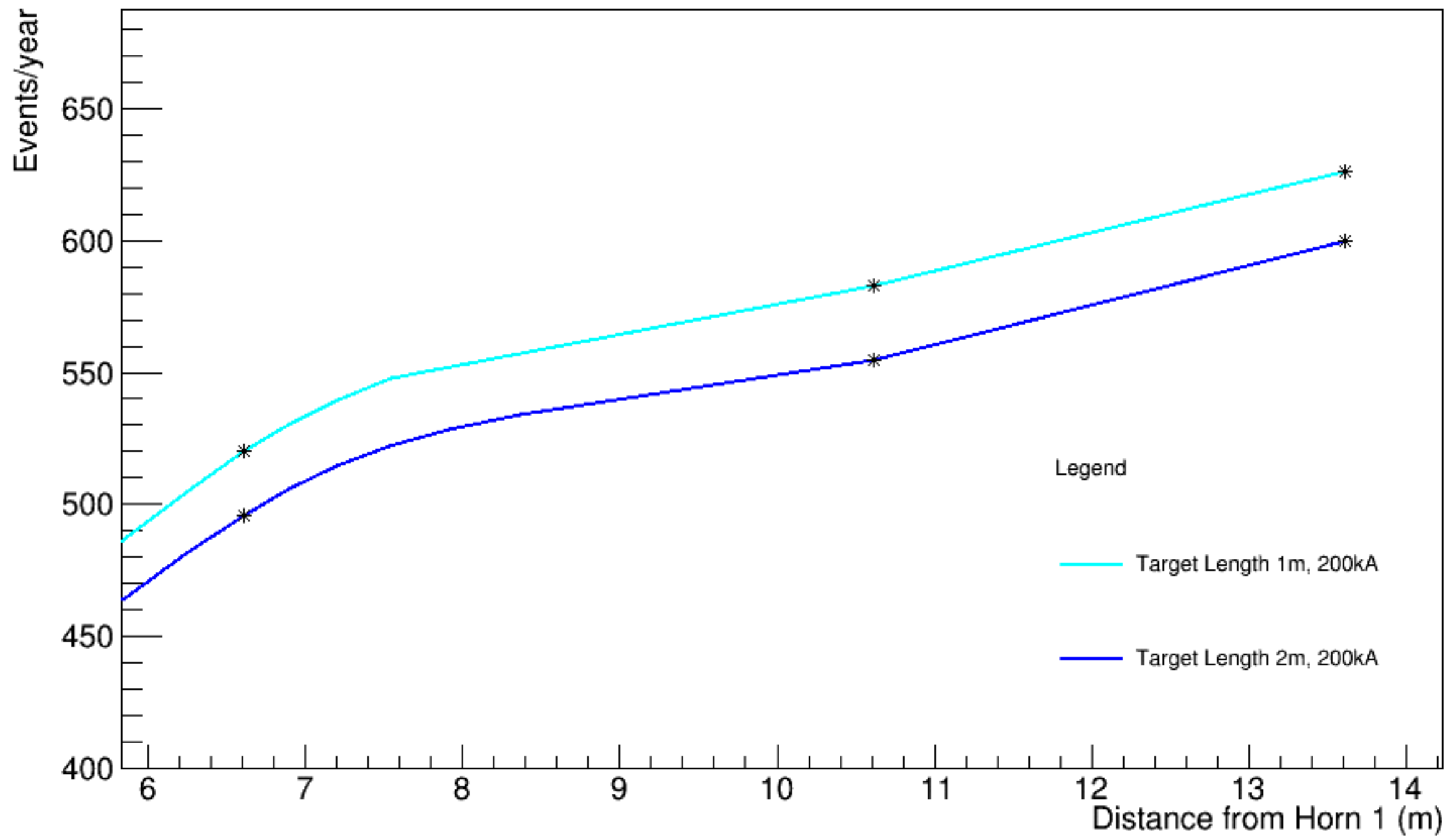


- Then, at 200kA, compared the target length of 1m to the target length of 2m in the referenceGeometry design at 0m (6.6m) and 7m (13.6m) distances (slides in Back-up).

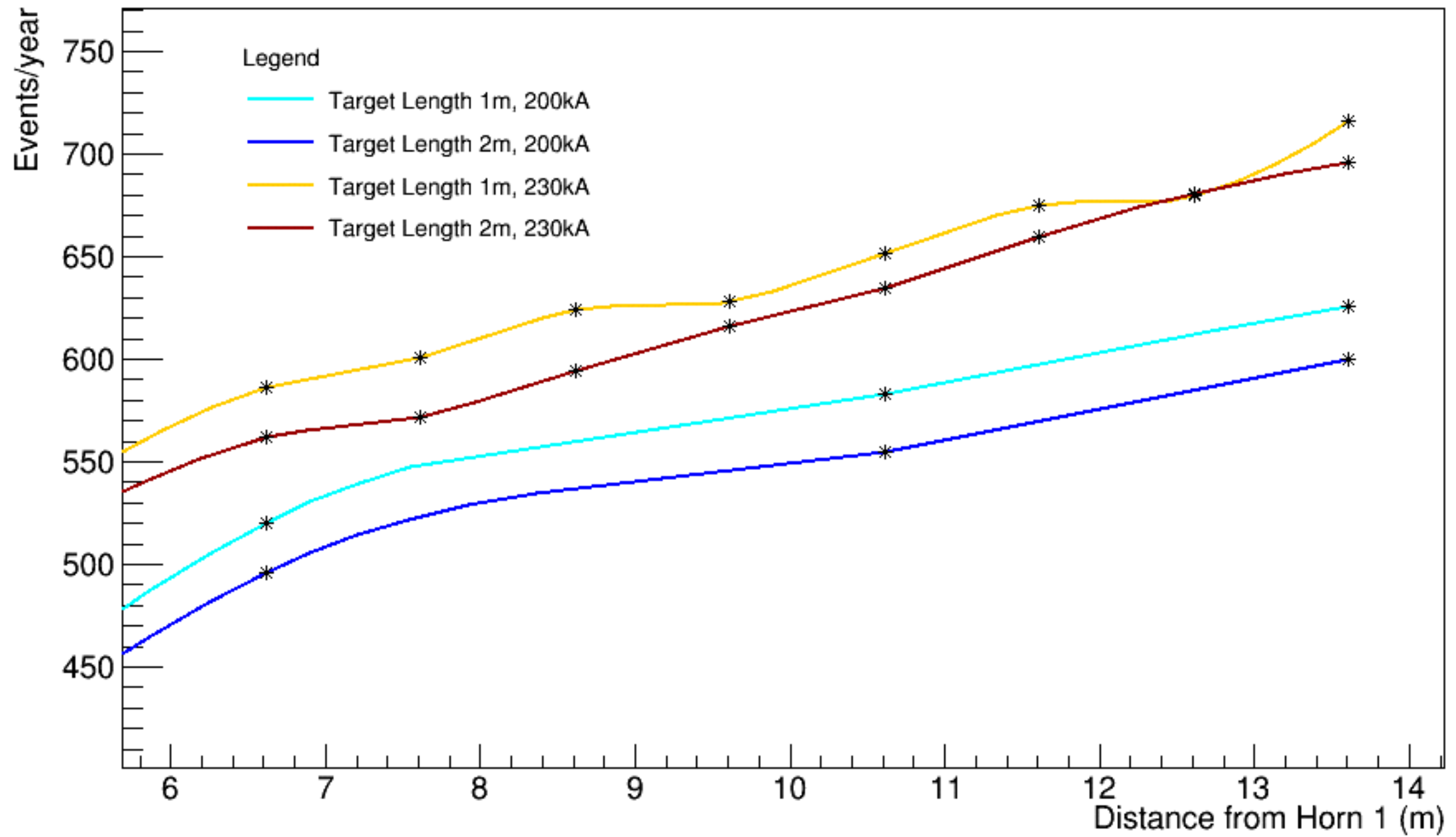
Target Length: 1m vs. 2m
Target Distance to Horn 1: 1.5m
Horn Current: 200kA

Horn 2 Distance from Horn 1 (m)	Rate (events/yr) for Target Length 1m	Rate (events/yr) for Target Length 2m
6.6110	520	495
10.6110	583	555
13.6110	626	599

Events/Year vs. Horn 2 Location



Events/Year vs. Horn 2 Location



Conclusion

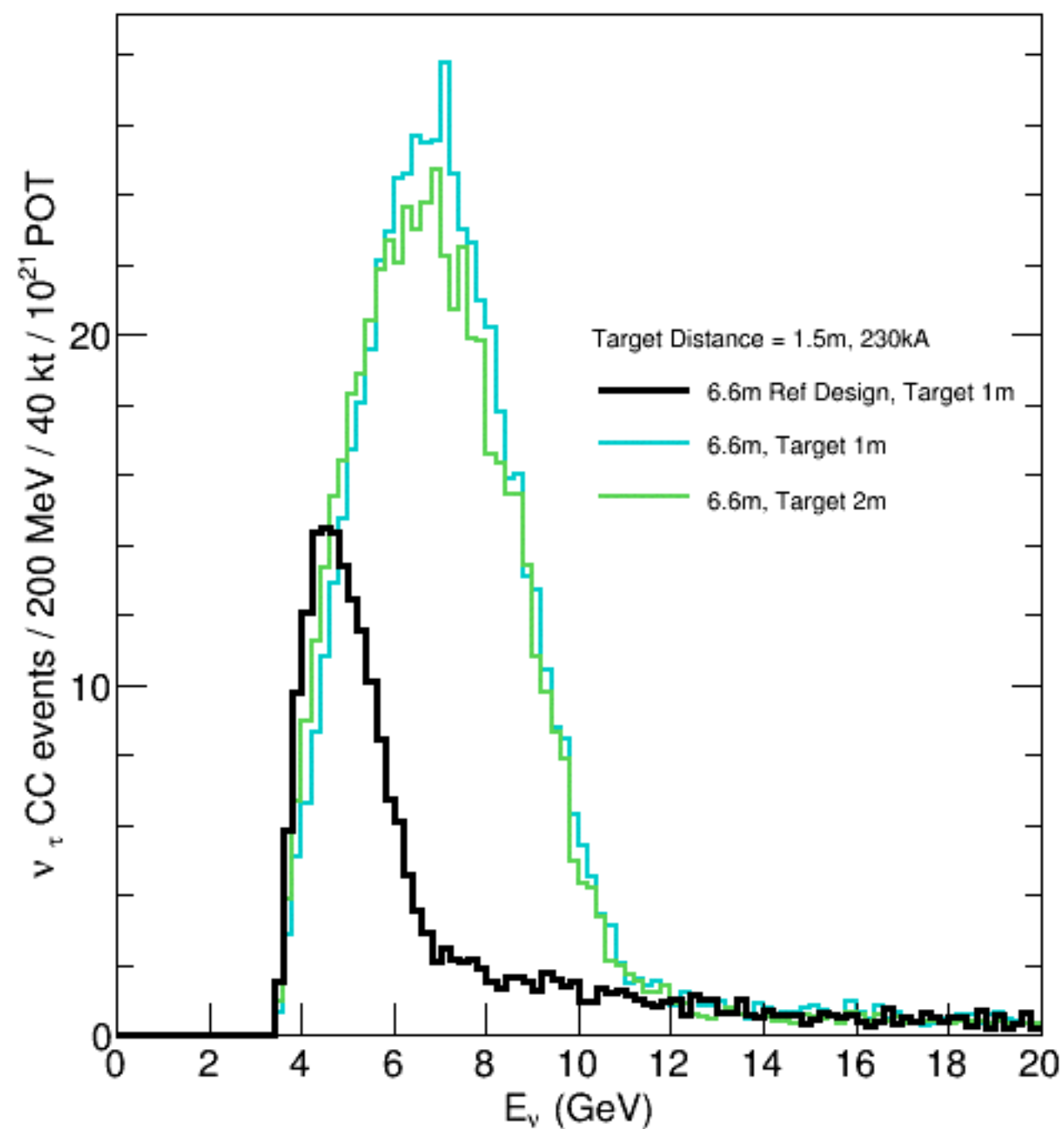
- For a maximal number of tau neutrino events, the best configuration would be with 230kA in the horns.
- With a 230kA current, it would be best to move horn 2 downstream to the end of the tunnel. This would allow a target length of 2m to be used without a significant loss of tau neutrino events, plus an increase in muon neutrino flux.

To-do list

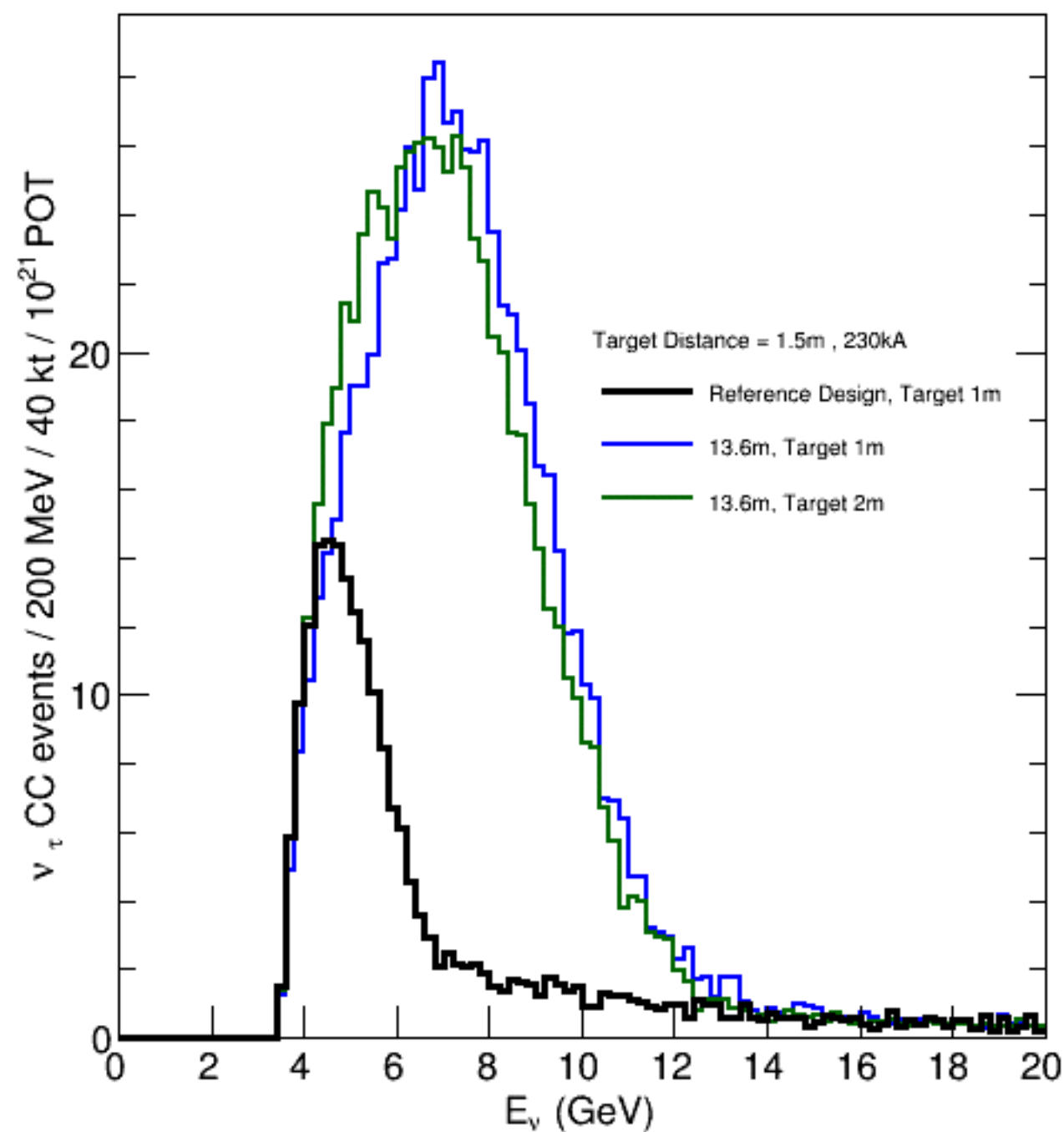
- Having analyzed the events with the target 1.5m back from horn 1, move the target 2m back.
- Move the target 2.5m back from horn 1.
- Compare the referenceGeometry (two horns) to the optimizedGeometry (three horns), changing the of target lengths, current, and target location.

Back-up Slides

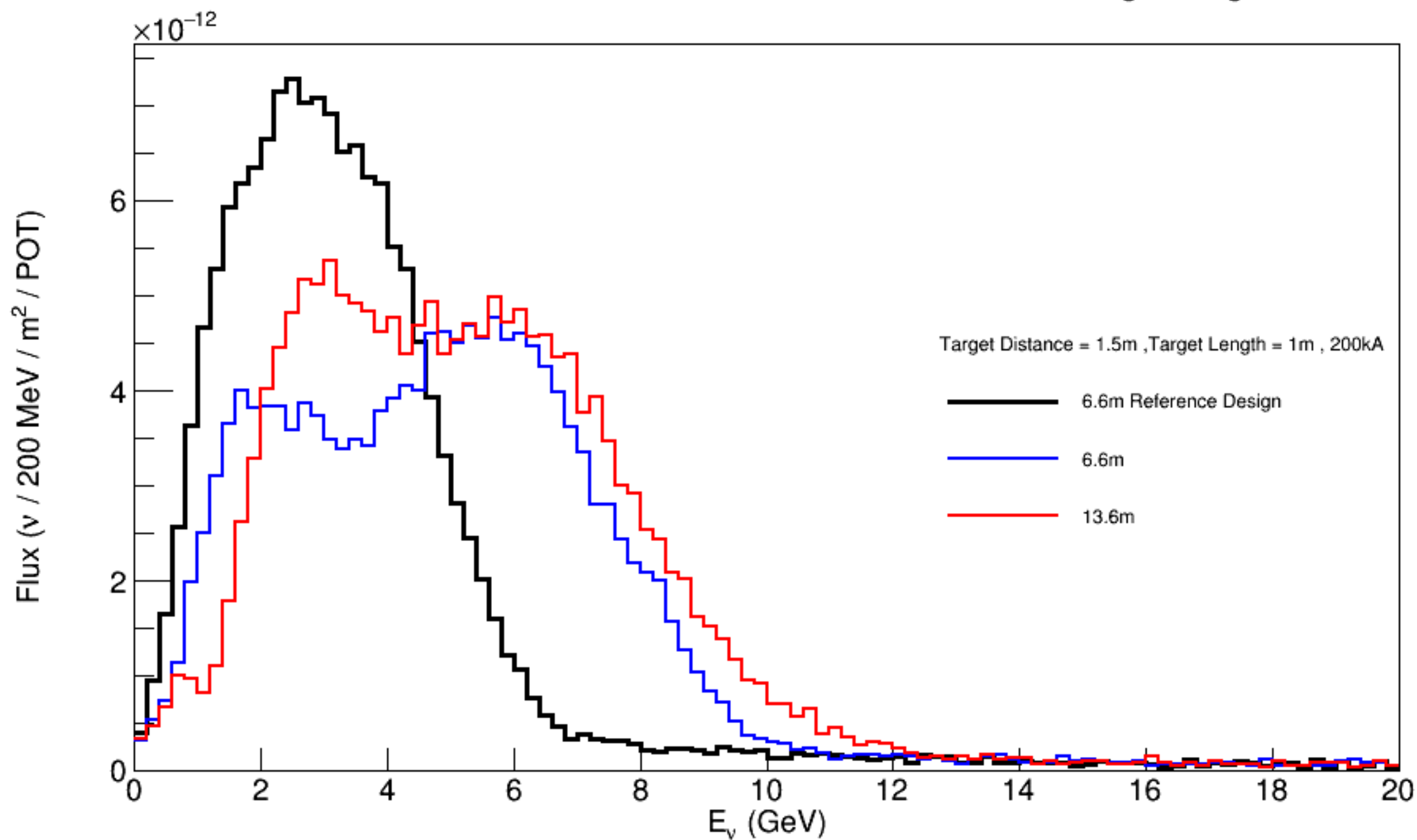
ν_τ events with 1m & 2m Target Length and 230kA



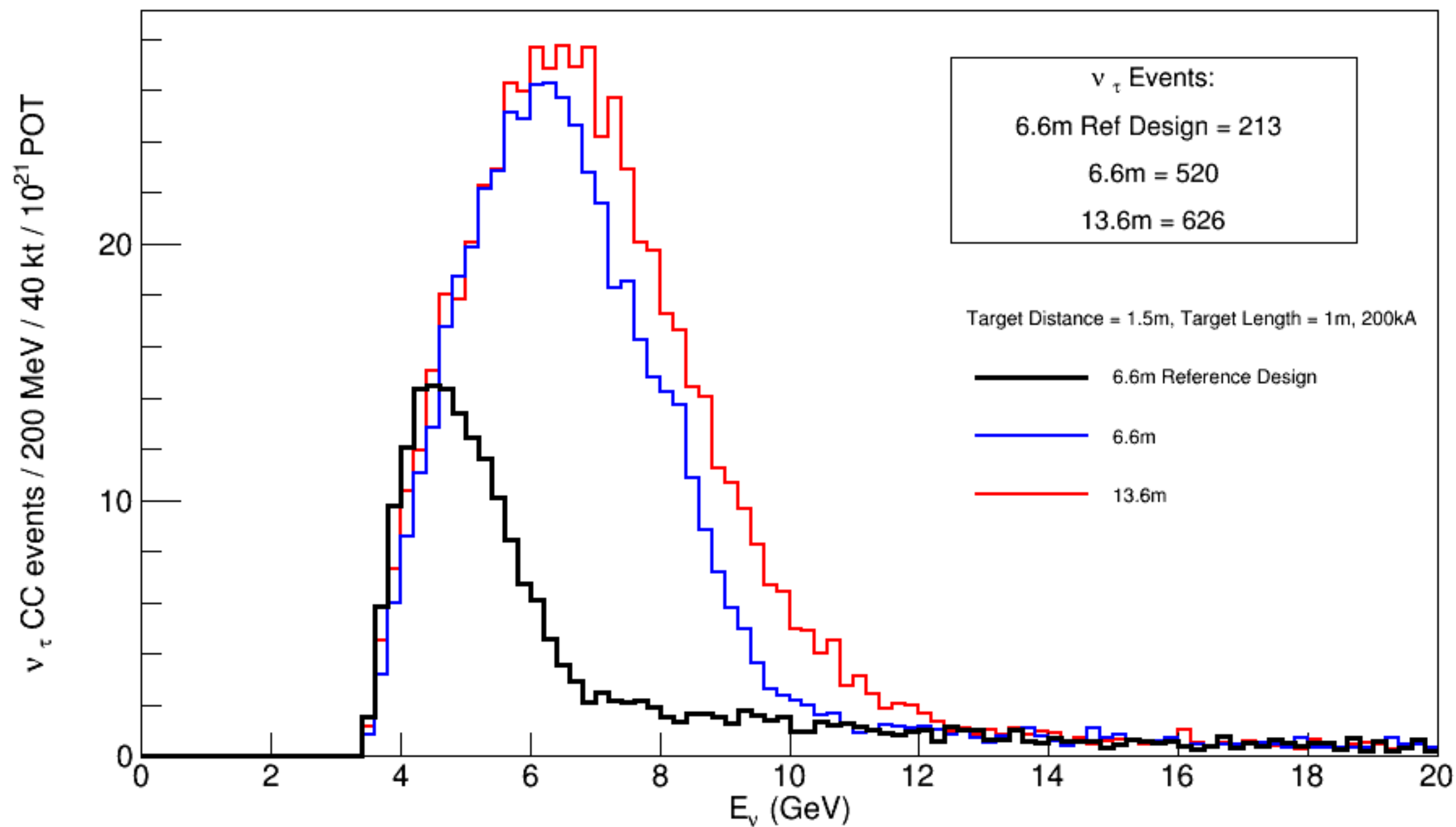
ν_τ events with 1m & 2m Target Length and 230kA



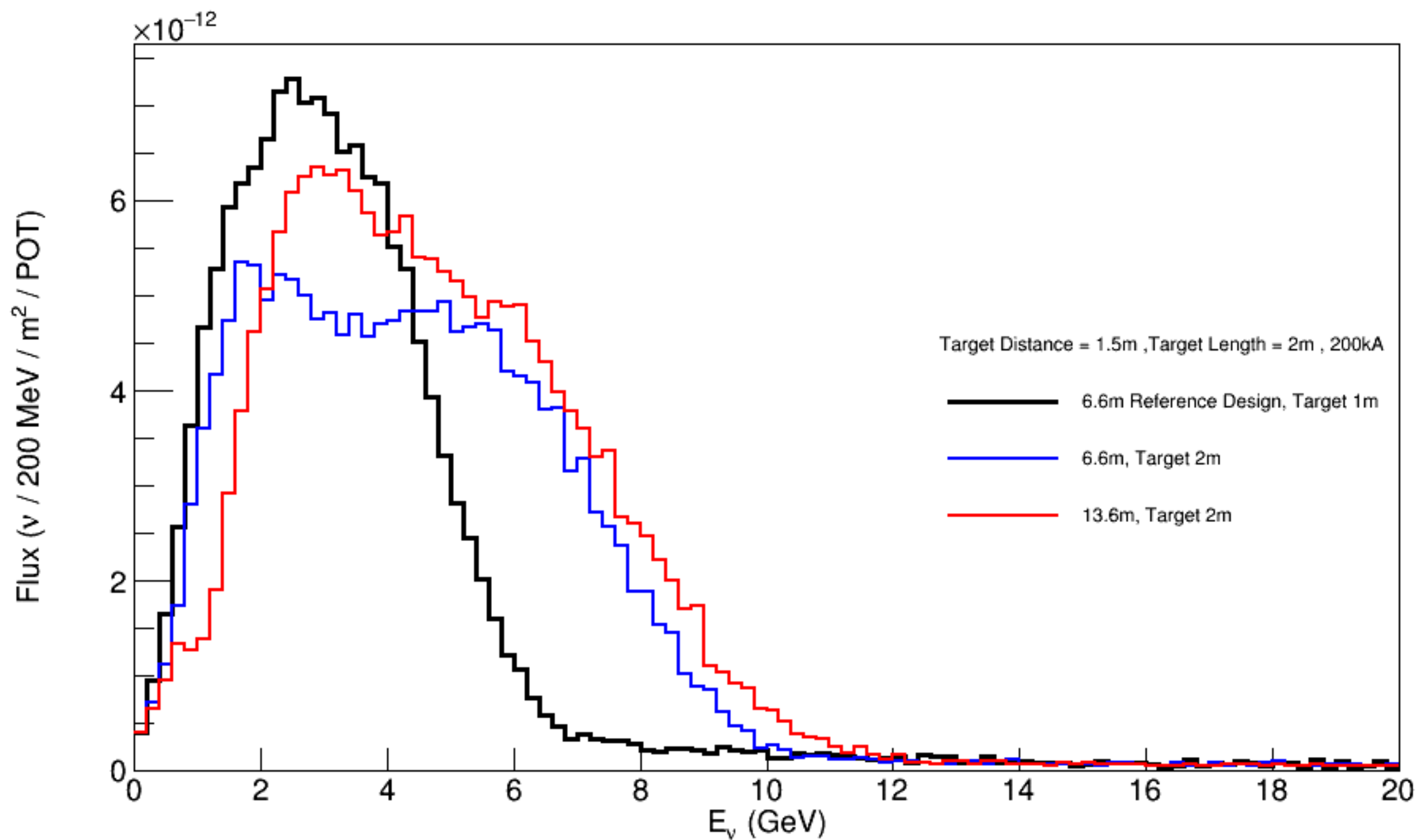
Muon Neutrino Flux of Horn 2 Moved Downstream w/ 1m Target Length



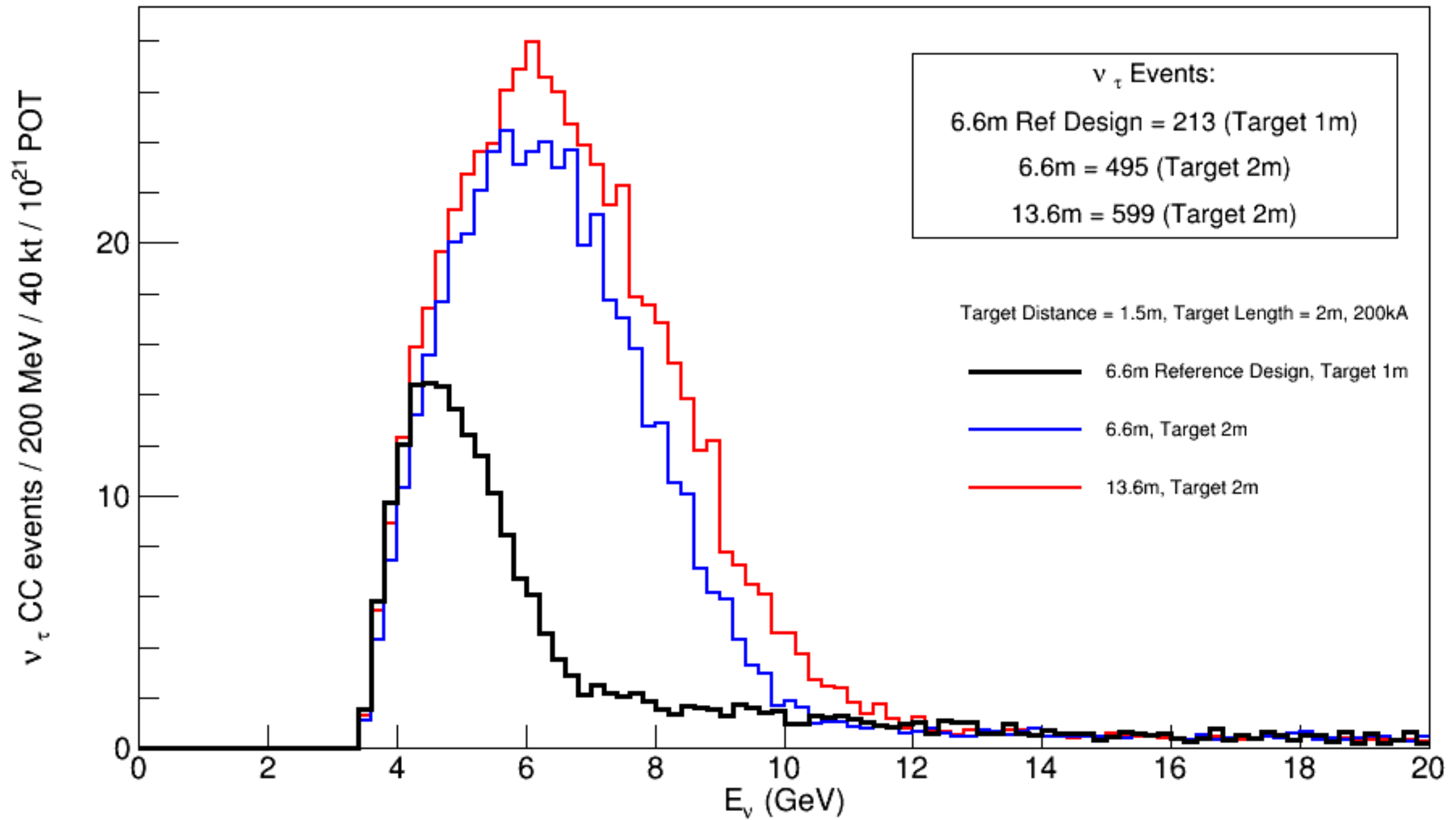
ν_τ CC events with Horn 2 Moved Downstream w/ 1m Target Length



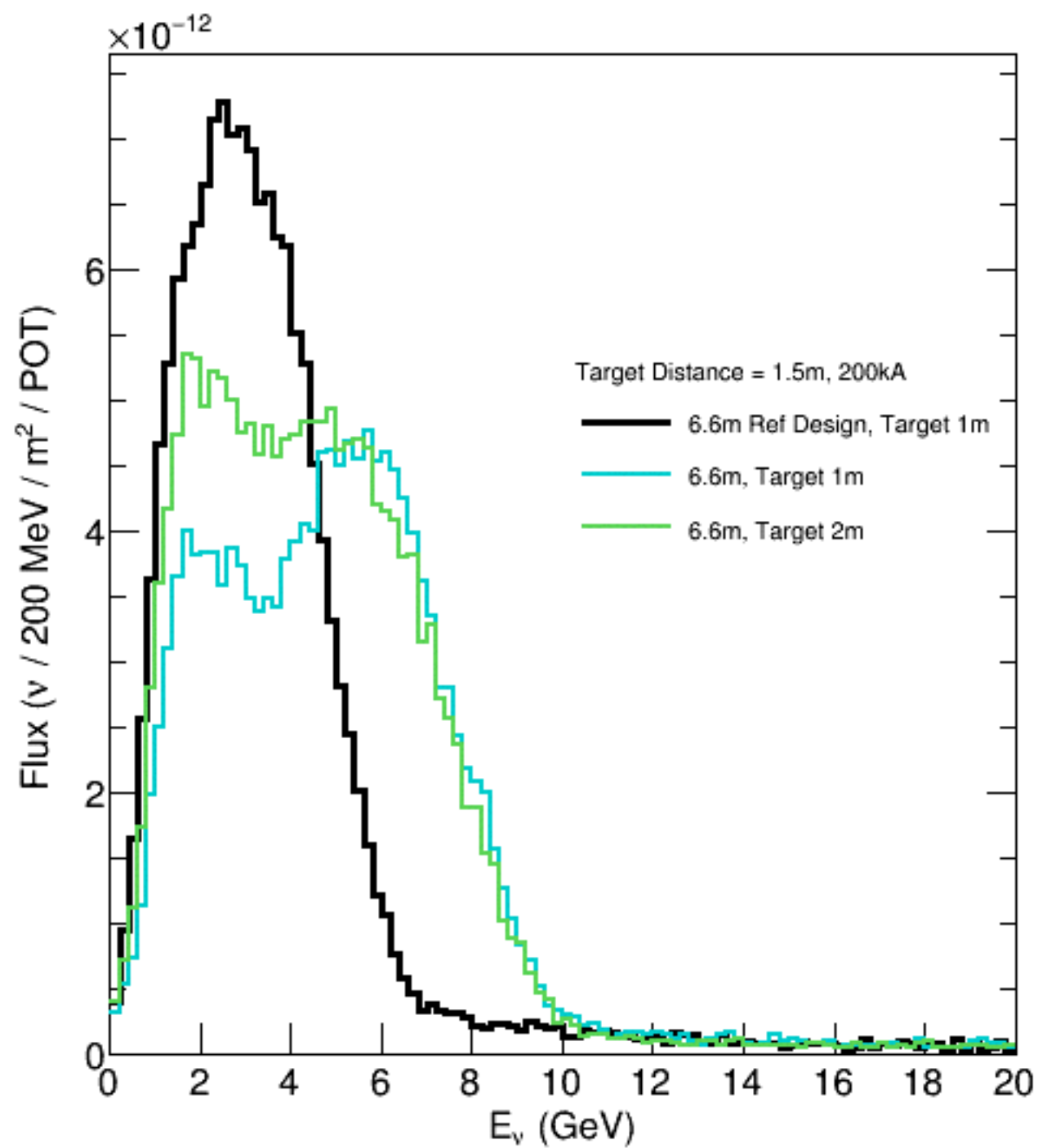
Muon Neutrino Flux with Horn 2 Moved Downstream w/ 2m Target Length



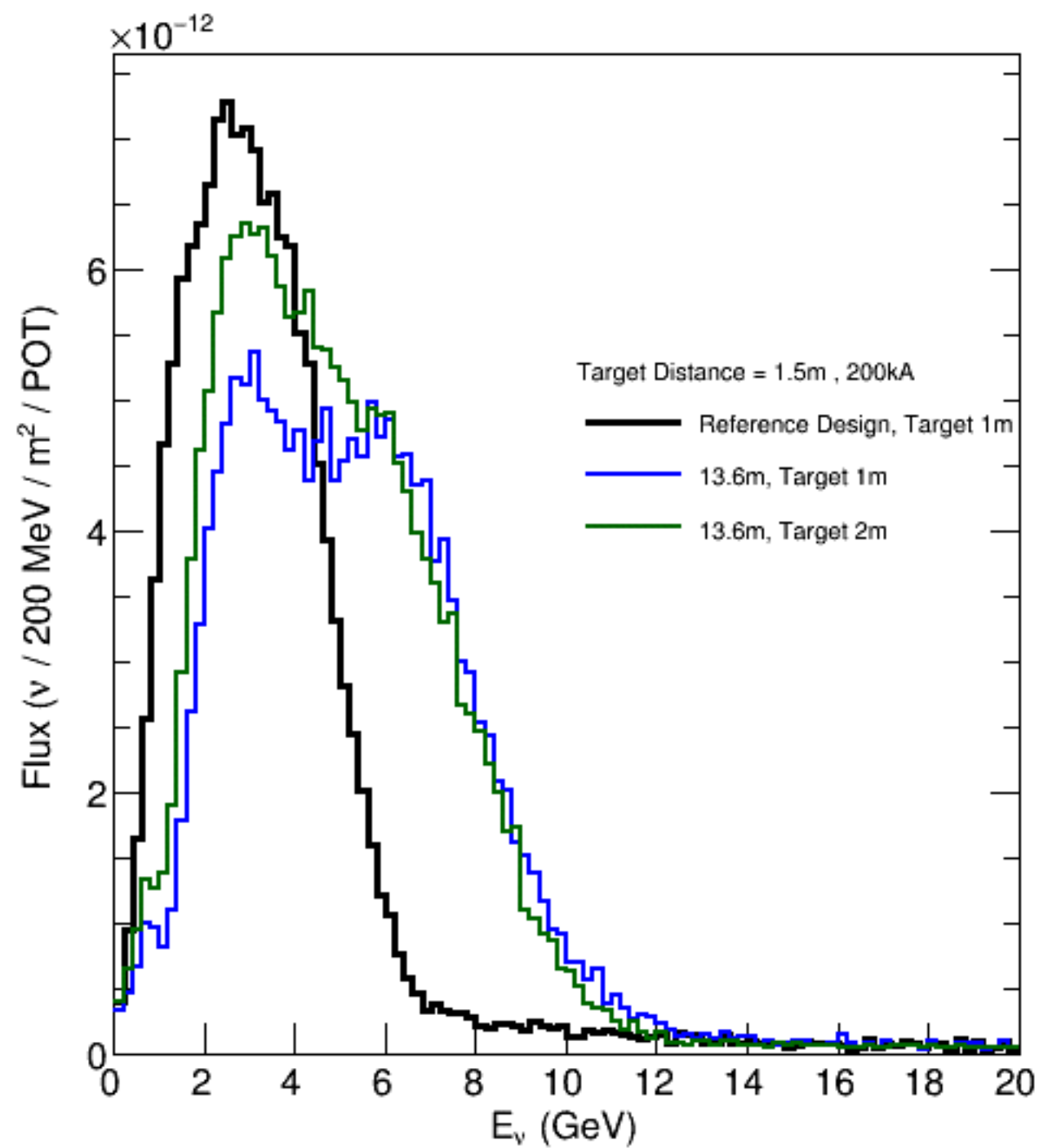
ν_τ CC events with Horn 2 Moved Downstream w/ 2m Target Length



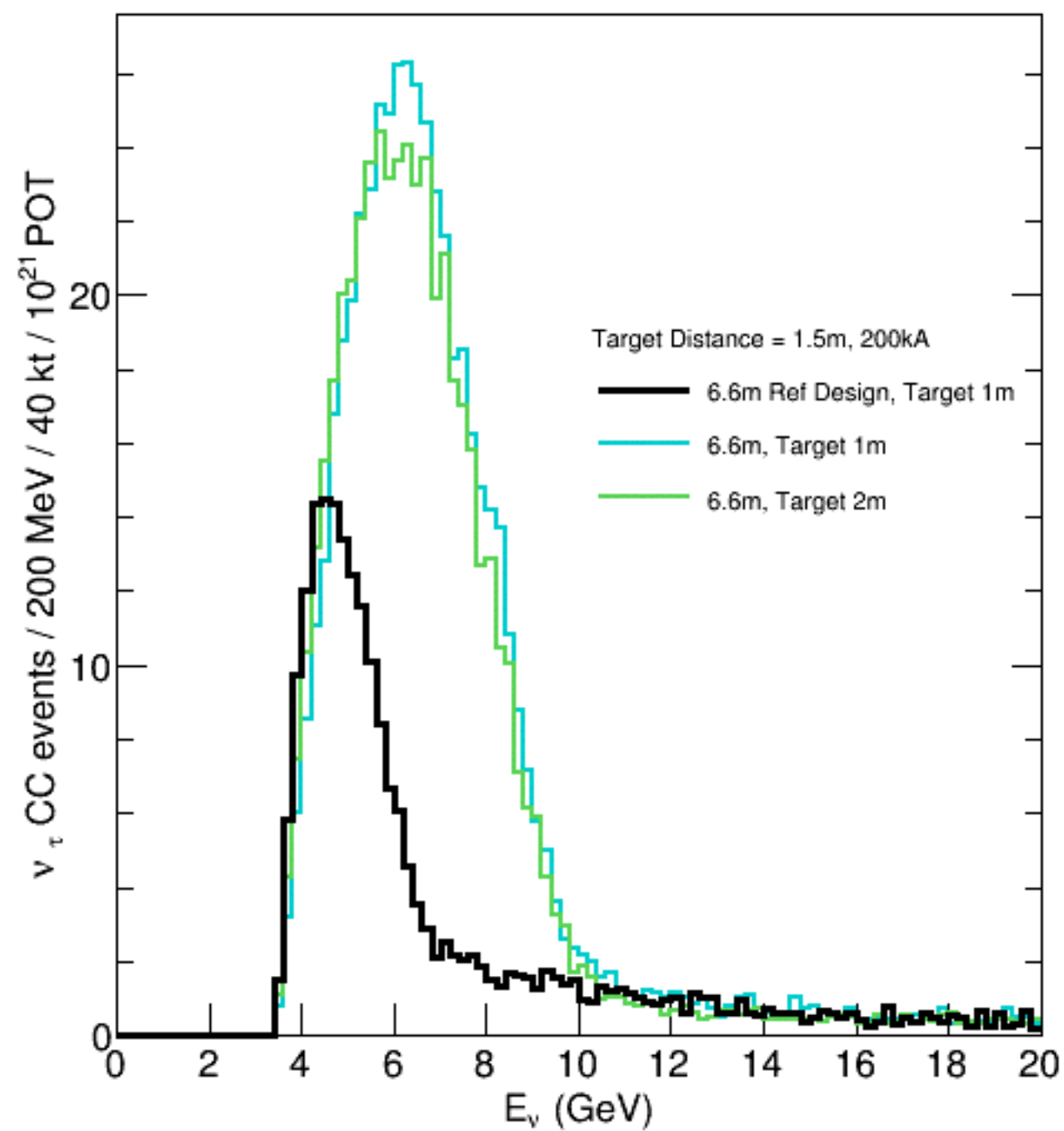
ν_μ Flux with 1m & 2m Target Length and 200kA



ν_μ Flux with 1m & 2m Target Length and 200kA



ν_τ events with 1m & 2m Target Length and 200kA



ν_τ events with 1m & 2m Target Length and 200kA

